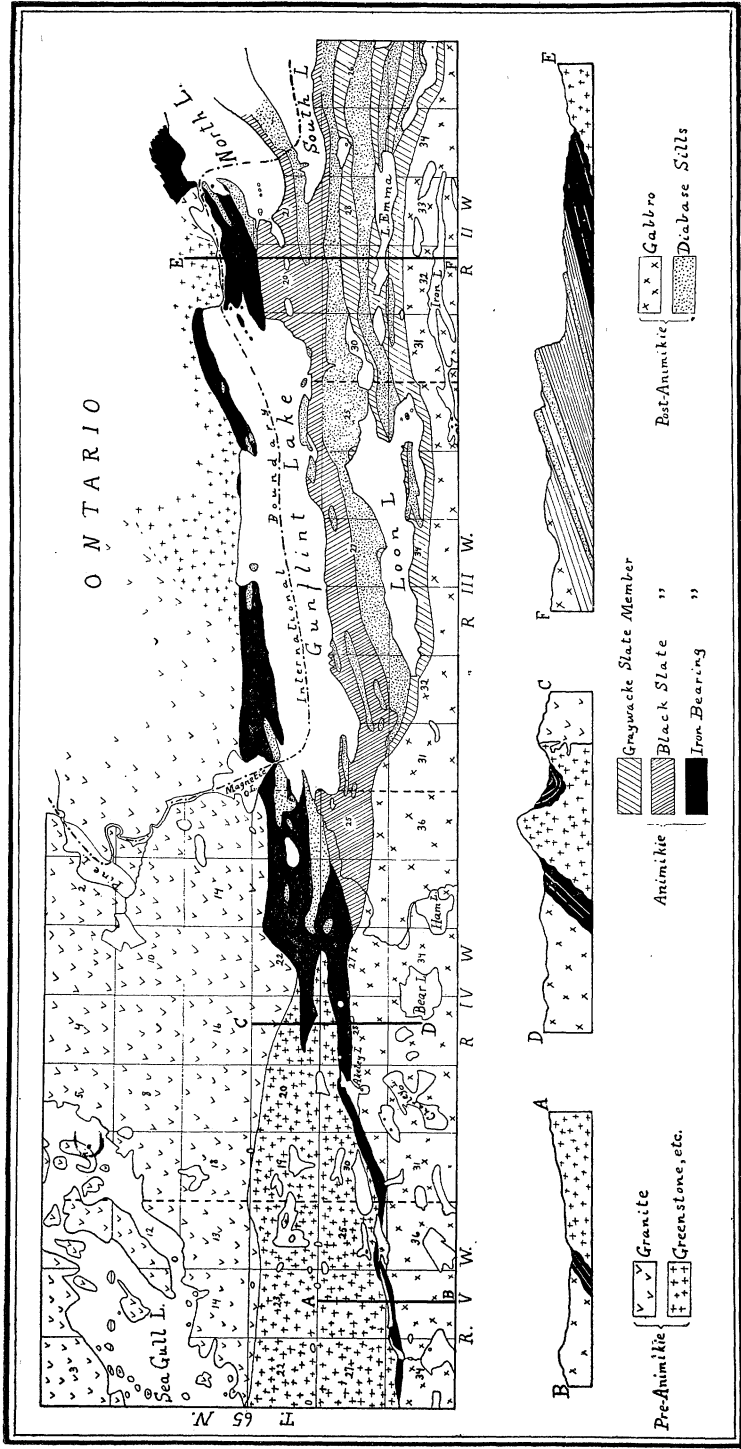


SKETCH OF THE GEOLOGY
OF THE EASTERN END OF THE
MESABI IRON RANGE
IN MINNESOTA

BY U. S. GRANT

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GEOLOGICAL MAP OF THE MESABI IRON RANGE IN COOK COUNTY, MINNESOTA.

Compiled by U. S. Grant from field notes of the Geological and Natural History Survey of Minnesota. The data for the geological boundaries on the Canadian side of the map are very incomplete. The horizontal scale of the sections is twice that of the map, and the vertical scale is several times that of the horizontal scale.

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INTRODUCTION.

On the west the rocks of the Mesabi iron range first appear at Pokegama Falls on the Mississippi river in Itasca county. From this point they extend in a general east-northeasterly direction through the southeastern part of Itasca county and the central part of St. Louis county. Throughout this distance, nearly one hundred miles, the Mesabi rocks lie on the southern slope of a range of granite hills, known as the Giants range, and toward the east they are immediately overlain by a mass of later igneous rock,—the great gabbro mass of northeastern Minnesota. This gabbro gradually encroaches upon the lower and the lower parts of the Mesabi rocks until the latter are completely covered, and the gabbro lies directly upon the granite; this occurs on Birch lake on the eastern border of St. Louis county. From here eastward through Lake county the Mesabi rocks appear only in a few areas of limited extent at or

*The information here presented was obtained largely by the writer in the summers of 1892 and 1893, while working under the direction of the State Geologist, Prof. N. H. Winchell, for the Geological and Natural History Survey of Minnesota.

near the northern edge of the gabbro. But in Cook county, near its western edge, they again emerge from beneath the gabbro mass and extend eastward as far as Port Arthur and the east side of Thunder bay on the north shore of lake Superior.

The Mesabi iron-bearing rocks occupy a belt some eighteen miles in length in Cook county and then pass into Canadian territory at North lake. It is with this portion of the Mesabi iron range,—i. e., that lying in the northwestern part of Cook county,—that this paper deals. The district described is shown on the accompanying map which includes T. 65 N., Rs. 3 and 4 W., parts of Rs. 2 and 5 W., and some adjacent portions of Ontario.

PHYSICAL FEATURES.

The land was originally densely timbered with pine, spruce, balsam fir and birch, and in some places good groves of white and Norway pine still exist. Considerable areas have been devastated by forest fires and such areas are now covered by a dense second growth of poplar and birch. The soil is usually not thick, and the bare, glaciated, underlying rock frequently appears at the surface. The subsoil, where such exists, consists of glacial deposits which are commonly not more than a few feet in thickness. While the general appearance of the district would impress a farmer very unfavorably, still the dense timber evinces a fertile soil and it can be said that districts less attractive from an agricultural point of view are cultivated successfully in the eastern states.

The surface in general is broken and rough, though by no means mountainous. Steep hills rising one hundred or more feet above the surrounding country are common and usually have an east and west direction. The most marked elevation is a hill range of greenstone and granite which runs through the center of T. 65 N., R. 4 W. This is part of the Giants range and in one place (north side of Sec. 28, T. 65 N., R. 4 W.) it rises to 2,038 feet above sea level,—the highest point in the area here described,—while altitudes of 1,800 feet are common. The lowest part of the district is Sea Gull lake which is 1,440 feet above the sea. Thus the extremes of altitude differ by practically 600 feet.

ELEVATIONS IN FEET ABOVE SEA LEVEL.

South Lake.....	1,558
North Lake.....	1,550
Lake Emma.....	1,850*
Iron Lake.....	1,853
Gunflint Lake.....	1,547
Magnetic Lake.....	1,547
Loon Lake.....	1,745
Ham Lake.....	1,706
Bear Lake.....	1,748
Charley Lake.....	1,763
Akeley Lake.....	1,779
N. ¼ post Sec. 28, T. 65 N., R. 4 W.	2,038
Pine Lake.....	1,465*
Sea Gull Lake.....	1,440*

In the eastern half of the area shown on the map is a peculiar type of topography, which is characteristic of much of the northern part of Cook county and adjoining parts of Ontario. This type of topography, which in this region is confined to the area underlain by Animikie (or Mesabi) rocks, consists of long, parallel, monoclinal ridges running approximately east and west, with sharp mural escarpments on the north sides of the ridges and on the south, gentle slopes. Between the ridges and running parallel with them are long, narrow lakes. A general section, from north to south, through these ridges, is as follows: First, a long lake, and on the south side of the lake a steep talus slope, above which is a cliff, composed of slates dipping southward at an angle of about ten degrees. The top of the cliff is made by a sill of diabase, which has been intruded between the beds of slate. Beyond the top of the cliff the land generally rises for a short distance, until coming almost to the top of the diabase sill. Then begins a long, gentle, southward slope about on the upper surface of the sill. This slope, however, does not extend far enough to bring the land down to the level of the northern foot of the ridge, but beyond the gentle slope is another lake, considerably higher than the first, and on the south of this lake the talus, the cliff and the gentle southward slope are repeated. (Compare section EF on the accompanying map.)

*From aneroid readings; all others from levels.

As an example of how the general land surface and lake levels rise toward the south, we may cite Gunflint lake, which is 1,547 feet above the sea level, while less than a mile to the south is Loon lake, with an altitude nearly 200 feet greater.

The abundant lakes, elongated in an east and west direction, as well as the numerous northward facing escarpments, suggest at once the probability of a series of comparatively recent east and west faults along the north sides of which the downthrow has occurred. But a rather careful examination of the rocky structure of the district has brought forward no confirmatory evidence along this line; in fact it has produced evidence which is directly opposed to the existence of any considerable east and west faults. It seems that the present configuration of the surface could have been brought about by pre-glacial erosion acting on gently inclined strata of different degrees of resistance, the thin bedded and fissile slates being much more susceptible to disintegration and erosion than the diabase sills.

The district here described lies in two great continental drainage basins, that of the Hudson bay and that of the Gulf of St. Lawrence. On the International boundary line the divide between these two systems of drainage is the portage between South and North lakes. The former lake is 1,558 feet above sea level and the latter 1,550 feet, and on the portage a height of 1,600 feet is not attained. The waters of South lake and of some of the small lakes in the extreme southeastern part of the area flow eastward through the Arrow and Pigeon rivers into lake Superior, while North lake and all the rest of the district drains westward and northward to Saganaga lake, which lies in the northwest corner of Cook county just north of the lake called Sea Gull lake on the accompanying map. From Saganaga lake the waters flow westward along the north side of Hunters' "Island" and finally into Hudson bay.

OUTLINE OF GEOLOGICAL HISTORY.

In this area the rocks are easily separated, both on lithological and on structural grounds, into three divisions, the chief one of which is the Animikie series, containing the iron-bearing rocks of the Mesabi range. Older than these are the

Pre-Animikie rocks, while younger than the Animikie are some diabase sills and the great gabbro mass.*

The Pre-Animikie consists of granites, greenstones, both massive and schistose, conglomerates, slates and other clastic rocks. These were deposited, complexly folded, elevated above the sea level, profoundly eroded and sunk again below the sea level before the time of the Animikie rocks, which are found resting unconformably upon the upturned and eroded edges of the older Pre-Animikie. Some time after the deposition of the Animikie strata they were intruded by igneous matter which formed large sheets or sills of diabase between the different strata. Also later than the Animikie came the gabbro, a great mass of igneous rock which usually overlies the Animikie, although in some places it is intrusive into the earlier strata. In general, these three divisions of rocks occupy east and west belts, the Pre-Animikie being confined to the northern part of the district, the Animikie to the central, and the gabbro to the southern. Thus in traveling from north to south, one passes over newer and newer rocks.

There are no rocks in this area later than the igneous rocks mentioned above, except some small dikes of uncertain, though probably Keweenawan, age. The whole district has been glaciated and striated surfaces and roches moutonnees are abundant; in fact, all the disintegrated rock was removed by glacial action. The general direction of the last ice movement, as shown by glacial striæ, was almost exactly south. Comparatively little is known concerning the deposits of drift in this district.

THE PRE-ANIMIKIE.

The rocks included in this division can be readily separated into two parts, the greenstone and the granite. Associated with these are other rocks in part of clastic origin, such as conglomerates, slates, graywackes and schists of various kinds. These latter and the greenstone have all been included under one term and called Keewatin, but as the greenstone is the only one of these Keewatin rocks which is intimately associated

*The Pre-Animikie rocks here described, according to the nomenclature used by the United States Geological Survey, belong to the Lower Huronian series of the Algonkian system and probably also in part to the older Archean or Basement Complex; the Animikie is regarded as the equivalent of the Upper Huronian series of the Algonkian, and the gabbro as the lower part of the Keweenawan series of the Algonkian.

with the Mesabi iron-bearing rocks in this area it need be the only one to be here described. However, on the Canadian side of Gunflint lake other rocks of the Keewatin appear.

The Greenstone.

Lying just to the north of the iron-bearing Mesabi (Animikie) rocks in T. 65 N., R. 5 W., and extending eastward to the center of T. 65 N., R. 4 W., where it disappears under the Animikie strata, is a belt, averaging about two miles in width, of rocks which have been called greenstones because of their general dark greenish color. They are crystalline rocks composed essentially of a ferro-magnesian mineral, which is almost always green hornblende, and plagioclase feldspar. These rocks vary exceedingly, even within short distances, at one place being quite coarse grained and granitic in texture and in another place being quite fine grained. The hornblende varies much in amount and frequently makes up almost the entire rock. In general, these rocks are at present diorites. At places, especially along the east side of Sec. 27, T. 65 N., R. 5 W., the greenstones contain angular and sub-angular fragments of rock almost like themselves, but nothing like a true conglomerate has been found in the area designated as greenstone. Nor is there any positive evidence of any sedimentary rock within the greenstone area in Minnesota shown on the accompanying map.

While the original nature of all the rocks here called greenstone cannot be stated positively, it is certain that they are essentially igneous in origin, although some parts may be regarded as composed of fragmental volcanic rocks. In lithological character some of these greenstones were certainly diabases and others were of the nature of andesites, while a large part seem to have been diorites or possibly gabbros. They have been subjected to much alternation and recrystallization, and it seems likely that parts of them have been altered more than once since their original formation.

Associated with the greenstones, especially in Secs. 22, 23 and 24, T. 65 N., R. 5 W., are some small masses of more acid rocks,—quartz porphyries and quartzless porphyries,—all of which are probably younger than the greenstones. While the evidence for each small mass is not complete, the following facts point to the truth of the above statement as to the age of

these more acid rocks: (1) They sometimes occur in the form of small dikes in the greenstones. (2) When in larger masses they sometimes show a finer grain at the contact lines with the greenstones than at some distance from these lines. (3) They have not acquired the schistose structure which is frequently, though by no means universally, developed in the greenstones. It can be stated that the greenstones as a rule are massive and cannot be called "greenstone schists" except locally.

The Granite.

The northern part of this area is covered by a mass of granite which, on account of its extensive and typical development on the shores of Saganaga lake (just north of Sea Gull lake), has been called the Saganaga granite. This rock is a coarse grained hornblende granite. The coarse grain, uniform character and large quartz grains, sometimes half an inch across, are characteristic features of this granite mass.

Along the southern border of the granite, as it approaches and is in contact with the greenstone, the grain becomes finer than usual and the quartz in places almost entirely disappears. Along this edge of the granite mass its relation to the greenstone can be distinctly seen in many places. At one locality (less than one-fourth mile south of the N. E. corner Sec. 23, T. 65 N., R. 5 W.) many granite dikes, from one to twenty-five feet in width, are seen cutting the greenstone. At another place (south shore of West Sea Gull lake) is a bold bluff of greenstone cut in every direction by branching vein-like forms of granite of the same nature as the immediately adjoining main mass of Saganaga granite. And the greenstone and these granite dikes themselves are also cut by another series of finer grained and more acid granite (aplite) dikes.

THE ANIMIKIE.

The Animikie rocks are the rocks of the Mesabi iron range and as such are of importance both economically and geologically. As developed in the district under consideration they are the equivalents, both in age and origin, of the rocks of the

productive portion of the Mesabi iron range to the west in St. Louis county.*

Throughout the extent of the Mesabi range the Animikie rocks, dipping usually at a small angle to the south, rest comfortably upon the older Pre-Animikie rocks, and usually upon the southern slope of the Giants range of hills which is composed essentially of granite. The strike is approximately east-northeast, with some local exceptions. In the district here considered the surface outcrop of the Animikie, as shown on the accompanying map, varies from nothing to something over three miles, and the thickness from nothing to nearly 4,000 feet, while the dip is in general about ten degrees a little east of south.

The rocks of the Mesabi range are readily separable on lithological and stratigraphical grounds into four conformable divisions or members which are as follows, beginning with the lowest or oldest: (1) The lower, or quartzite member, called the Pewabic quartzite; (2) the iron-bearing or taconyte member; (3) the black slate member; (4) the graywacke slate member. The quartzite member is well developed in Itasca county, but gradually becomes thinner and thinner in surface outcrop towards the east and before reaching the eastern side of St. Louis county has entirely disappeared; nor does it reappear in Cook county.

An estimate of the maximum thickness, in feet, of the different members as exposed in that part of Cook county here described is as follows, the estimate being based on the assumption that there are no east and west faults which would make the apparent thickness greater than the real:

	Sediments.	Diabase.	Totals.
Graywacke slate member.....	1,650	250	1,900
Black slate member.....	950	100	1,050
Iron-bearing member.....	825	75	900
	<u>3,425</u>	<u>425</u>	<u>3,850</u>

*For an account of the geology and ore deposits of the productive portion of the Mesabi range see:

H. V. Winchell: Geol. and Nat. Hist. Survey of Minn., 20th Ann. Rept., pp. 111-180, 1893.

J. E. Spurr: Ibid., Bull. 10, 1894.

The Iron-bearing Member.

Towards the western edge of Cook county this member first appears, between the greenstone on the north and the gabbro on the south, near the center of the west half of Sec. 34, T. 65 N., R. 5 W. (See map.) It extends eastward, holding the same position with respect to the adjoining rocks, as a narrow belt for about six miles when it rapidly widens and soon attains a width of over a mile. At the western end of Gunflint lake the iron-bearing rocks leave Minnesota territory, but reappear on the broad point between Gunflint and North lakes. They outcrop in many places at and near the north shore of Gunflint lake and evidently underlie much of the northern half of this lake. To the east of the west end of North lake the iron-bearing member is not known in Minnesota, but it extends eastward in Ontario as far as Port Arthur on Thunder bay, north shore of lake Superior.

The dip of the iron-bearing member west of the center of Sec. 27, T. 65 N., R. 4 W., and south of the greenstone is toward the south, varying from twenty degrees to almost vertical, and the width of the outcrop is from 300 to 1,300 feet. The average dip is from forty-five to fifty degrees. Where this belt of rock is the widest the dip is about thirty degrees. This would indicate a thickness of 650 feet, which is probably the maximum thickness of these rocks west of the center of Sec. 27. To the east of this the dip is much less, averaging less than fifteen degrees, and the outcrop is much wider, being a mile and a quarter in width along the west side of Secs. 23 and 24, T. 65 N., R. 4 W. The thickness of the iron-bearing member also increases towards the east and reaches about 900 feet, of which 75 feet is diabase.

West of Sec. 27 the iron-bearing rocks lie low down on the southern slope of a prominent greenstone ridge which decreases in height in the northern part of this section until it disappears completely under the Animikie strata. These Animikie strata swing around to the north and pass from the greenstone onto the granite. A narrow belt of the iron-bearing rocks extends westward nearly to the western side of Sec. 21, T. 65 N., R. 4 W., being flanked both on the north and south by greenstone. The structure of this belt is synclinal and the Animikie rocks

evidently once extended, in the form of an anticline, over the high greenstone ridge, which now separates the two belts of the iron-bearing member. (See map, section CD.)

In general characters the rocks of the iron-bearing member in the district here described are quite similar to the rocks of the Mesabi iron range in St. Louis county. They differ, however, in two features,—first, they frequently are more completely crystallized than the same rocks of the western Mesabi, and second, the iron, instead of being in the form of hematite, is almost entirely magnetite. It will not be necessary to describe the lithological characters of the rocks of the iron-bearing member except to state that they consist chiefly of jaspers, amphibole (grünerite) schists, greenish siliceous slates, cherts, cherty carbonates and magnetite slates. They may all be conveniently included under the term taconyte*, which is a name commonly applied to the rocks of the iron-bearing member of the Mesabi range. These rocks are regarded as originally glauconitic green-sands, and the ore has been derived from the iron in the glauconite, the ore bodies being due to concentration and replacement†.

The narrow belt of iron-bearing rocks, lying west of the center of Sec. 27, T. 65 N., R. 4 W., differs from the rest of the rocks of the iron-bearing member in being highly crystallized. They consist of rather coarse-grained aggregates of the following minerals: quartz, magnetite, olivine, hornblende and augite. The marked banding which is characteristic of the taconyte rocks is still preserved in this crystallized portion of these strata which are made up of bands, varying in width from a fraction of an inch to a foot or more, composed of any one of the above minerals or of mixtures of them. The magnetite and quartz frequently form bands by themselves. The coarse crystallization of this portion of the iron-bearing strata is due to the effect of the gabbro upon the rocks with which it came in contact. All along the northern edge of the gabbro mass it has re-crystallized the older sedimentaries, and this effect can nowhere be better seen than in this belt of iron-bearing rocks, west of the center of Sec. 27. At the southwestern corner of

*H. V. Winchell: Op. cit., p. 124.

J. E. Spurr: Op. cit., pp. 248-249.

†J. E. Spurr: Op. cit.

Loon lake the recrystallizing effect of the gabbro on the gray-wacke slate member of the Animikie is also very apparent.

The Iron Ore. This consists almost entirely of magnetite, although a little hematite has been reported from near Gunflint lake, both on the Minnesota and Ontario sides of the boundary. The magnetite occurs disseminated through the rocks of the iron-bearing member, and it is also concentrated into numerous bands. Over large areas thirty to forty and even fifty per cent of the rock is magnetite. Towards the base of the formation the iron ore is more abundant and here are frequently found beds of almost pure magnetite. These beds vary in thickness from a few inches to three or four feet. The ore occurs in bands or beds and not in irregular or lens-shaped bodies as on the western portion of the Mesabi range. This, as well as the absence of very large concentrations of ore, is probably due to the fact that time enough had not elapsed, between the deposition of the Animikie rocks and the intrusion of the gabbro and of the diabase sills, to allow of the formation of large bodies of ore. The advent of the igneous rocks more or less crystallized the sedimentaries and changed the iron ore to magnetite,—in short reduced the rocks to such a condition that they did not present suitable conditions for the alteration of the ore and its concentration by circulating waters, while on the western Mesabi the formation of ore bodies has been able to go on even to the present day.

In the district here described no ore bodies have yet been found which are at the same time both rich enough and large enough for profitable mining at the present prices of iron ore. There are, however, vast quantities of this magnetite ore at and near the surface, and there seems to be no reason why it could not be profitably mined were the prices of ore a little higher than at present.

The following partial analyses show the general composition of the iron ore of this district:

	I.	II.	III.	IV.	V.
Metallic iron, Fe.....	58.40	54.01	63.98	62.05	55.60
Manganese, Mn.....	4.92	5.02	none		4.34
Silica, SiO ₂	8.22	9.37	8.90	7.14	10.02
Alumina, Al ₂ O ₃	.52	.07			.34
Phosphorous, P.....	.036	.032	.028	.113	.042
Titanium, Ti.....	none	none	trace		none

Exploitation. In 1886 and 1887 considerable exploratory work and some test pitting was done in the iron-bearing rocks at various localities west of Gunflint lake. A diamond drill was brought by wagon and canoe from Grand Marais on Lake Superior, and several drill holes were put down in Secs. 28 and 29, T. 65 N., R. 4 W. The rocks pierced in one place by this drill were reported as follows: siliceous rock, 30 feet; clean ore, 15 feet; mixed ore, 17 feet; clean ore, 10 feet; greenstone, 12 feet. The "clean ore" evidently was not pure magnetite, but was probably rock of nearly uniform composition consisting largely of magnetite. The results of the exploration and drilling led to the organization of the Gunflint Lake Iron Company, which began active operations in Secs. 28 and 29 in the spring of 1892. In the following winter the Port Arthur, Duluth and Western Railroad was completed to the company's headquarters in Sec. 28. Five miles of this railroad are in Minnesota territory. On the advent of the railroad machinery was obtained and a working shaft, eight by twelve feet in size, was sunk in the S. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ Sec. 28. This shaft reached a depth of 105 feet. A smaller shaft, on the north shore of Akeley lake in Sec. 29, was sunk to a depth of about 75 feet. No ore was shipped and the workings were abandoned in the fall of 1893.

The Black Slate Member.

This consists essentially of fine grained, black, more or less siliceous, apparently carbonaceous slates which are frequently quite fissile, although in a few exposures they are remarkably massive and might be easily mistaken in the field for fine grained, black, igneous rocks. In thin section typical specimens of these black slates are seen to be composed of numerous small, angular fragments of quartz in a cement of dark color and apparently carbonaceous character.

The Graywacke Slate Member.

This is composed of black to gray slates and fine graywackes, with some flinty slates and the upper part shows coarser detrital matter, while the highest beds seen in this area are fine grained quartzites and quartz slates. The strata of this member are well exposed along the south shore of Loon lake and especially along the north side of the long point on the

south side of the lake. Towards the west end of the lake some fine grained quartzites occur.

THE DIABASE SILLS.

Associated with all members of the Animikie are extensive sheets of diabase which have been intruded between the Animikie strata and which are now exposed over considerable areas. Indeed the hard resistant nature of these diabase sills renders them much more conspicuous than their actual number and thickness, as compared with the associated sediments, would warrant. All of the igneous rock associated with the Animikie in Minnesota is, as far as known, intrusive in its nature, and in the Animikie time there was no surface igneous activity. Thus it was an epoch of quiet and continuous sedimentation sharply in contrast with both the older Keewatin and the newer Keweenaw, both of which were times of widespread volcanic activity.

The diabase sills vary in thickness from a few feet to about 100 feet, or even more. The thickest one in the area here described is that shown on the map as extending along the north side of Loon lake. These sills, especially the larger ones, are quite coarse grained except near their upper and lower sides, where they become very fine grained and in places almost glassy. The adjoining Animikie rocks are altered for only a few feet from the contact of even the largest sills.

THE GABBRO.

Bounding the Animikie rocks on the south is the great gabbro mass of northeastern Minnesota. This gabbro is an igneous rock of later date than the Animikie. It is composed essentially of plagioclase feldspar (usually near labradorite) and augite, with some olivine and magnetite. At and near the contact of this igneous rock with the Pre-Animikie and with the Animikie sediments, it has produced a marked metamorphism and usually a complete recrystallization, as has been mentioned under the description of the iron-bearing member of the Animikie.

The gabbro is usually of uniform grain and composition, but varies sometimes in two distinct directions. In one the feldspar increases and the other minerals decrease in quantity

until a nearly pure plagioclase rock results, and in the other direction the magnetite, which is titaniferous, increases in amount until it forms all or nearly all the mass of the rock. Variation in this latter direction produces deposits of titaniferous magnetite which are not uncommon, and which sometimes reach considerable size. These deposits of titaniferous magnetite are not at present worked. Large amounts, however, of this ore exist and will be of value when they can be reduced as cheaply as non-titaniferous ores. Such deposits occur on Mayhew and Iron lakes, at the southeast corner of T. 65 N., R. 3 W. Analyses of the ore from this locality are as follows:

	I.	II.
Silica, SiO_2	2.02	20.90
Alumina, Al_2O_3	2.68	1.75
Titanium binoxide, TiO_2	12.09	2.23
Magnetic oxide of iron, Fe_3O_4	80.78	72.30
Chromium sesquioxide, Cr_2O_3	2.40	
Magnesia, MgO		2.63
Lime, CaO	trace	trace
Phosphorus, P.....	.03	none
	100.00	99.81
Metallic iron.....	58.48	52.46

Lately some excitement has been caused by the reported discovery of large percentages of nickel in the titaniferous magnetites of the gabbro in Cook county. Nickel does occur in similar situations and is frequently found as an impurity in one of the gabbro minerals (olivine), but as yet no reliable reports of nickel ore rich enough for mining have been received. A determination of the nickel in iron ore from the locality of the specimens above analyzed showed less than one-half of one per cent.